ESTCP
Cost and Performance Report

(EW-201252)

Demonstration Program for Low-Cost, High-Energy-Saving Dynamic Windows

September 2014

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Project: EW-201252

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

Page

LIST OF FIGURES

LIST OF TABLES

Page

ACRONYMS AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
CAPEX	capital expenditures
CO2e	Carbon Dioxide equivalent
DOD	U.S. Department of Defense
ESPC	Energy Savings Performance Contract
ESTCP	Environmental Security Technology Certification Program
FAR	Federal Acquisition Regulation
ft^2	square feet
GHG	greenhouse gas
HVAC	heating, ventilation, air-conditioning
IGU	insulated glass unit
ISO	International Organization for Standardization
JCI	Johnson Controls
LEED	Leadership in Energy and Environmental Design™
low-e	low emissivity
MCAS	Marine Corps Air Station
NREL	National Renewable Energy Laboratory
OPEX	operating expenditures
PO	performance objectives
ROI	return-on-investment
SHGC	solar heat gain coefficient
SIR	savings-to-investment ratio
UFC	Uniform Fire Code
UFGS	United Facilities Guide specifications
UV	ultraviolet
W	watt

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We would like to acknowledge the fantastic team at Marine Corps Air Station (MCAS) Miramar for their support and enthusiasm in this project. We would like to particularly thank Mick Wasco for helping make sure everything went so smoothly. Additional thanks go to the experienced and professional subcontractors that contributed to the successful completion of this project. They created a safe, clean environment for both the project team and the building occupants that continued to work on site throughout all phases of the project.

A final thanks goes to the ESTCP program and their vision of bringing forth technologies that will provide both energy security and a more sustainable future to our military infrastructure.

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EXECUTIVE SUMMARY

OBJECTIVES OF THE DEMONSTRATION

Inefficient windows in buildings represent one of the biggest energy problems in the military today. Facilities consume 30% of all U.S. Department of Defense (DoD) energy demand. This massive energy footprint costs taxpayers billions of dollars each year and impacts DoD mission assurance by straining fragile public electricity grids.

This ESTCP project demonstrated the benefits for DoD building energy efficiency by using dynamic windows, a new type of advanced “Smart Window” product, as compared to existing single pane windows or low-emissivity (low-e). These smart windows can automatically tint and untint throughout the day to minimize solar heat-gain in the summer, maximize passive heating in the winter and maximize the use of natural daylighting throughout the year. If broadly adopted, View’s dynamic windows technology could reduce global DoD energy consumption from buildings by 15% and greenhouse gas (GHG) emissions by 24%, representing an annual savings of ~$680M. At the same time, replacing existing windows with dynamic windows can reduce total facilities peak load by up to 25%, reducing strain on local electrical grid infrastructure, further improving energy security. Overall, the dynamic window technology addresses two of DoD’s three key installation energy goals, to: 1) reduce energy usage/intensity and 2) improve energy security.

The goal of this project was to validate the performance and life-cycle cost benefits of dynamic windows in an operational environment, generating the data and insights needed to create awareness and acceptance of the technology. The project was intended to facilitate future technology transfer across all DoD building-stock, while providing a direct benefit to our host base in terms of reduced energy consumption, reduced life-cycle cost, and improved occupant comfort. We accomplished these goals by pursuing the following objectives:

1. Install dynamic windows in a demonstration site on a DoD installation.
2. Monitor energy consumption, peak-load and occupant comfort before and after installation.
3. Develop detailed energy models for the site, calibrated against baseline and experimental energy results.
4. Use the calibrated models and historic weather data to predict the lifecycle energy savings (and resulting GHG and energy cost savings) at the site.
5. Use calibrated models to estimate reductions in peak-load energy use and improvement in occupant comfort to propose the ability to down-size the heating, ventilation, air-conditioning (HVAC) capacity and eliminate blinds/shades in future new construction and major renovation projects.
6. Quantify improvements in occupant comfort and satisfaction.
7. Quantify the total predicted life-cycle cost-, energy- and GHG-savings relative to state-of-the-art low-e windows at the site and across the entire DoD building stock.

8. Develop guidance documents and tools to assist with technology transfer across the DoD.

All goals for the project were met. Further, to accelerate the transfer of technology throughout the DoD, the project team also engaged with major DoD Energy Service Companies, including Johnson Controls Inc.(JCI) and Noresco, to enable and accelerate future installation through Energy Savings Performance Contracts (ESPC). Our collaboration with these companies in concert with this demonstration project will allow Federal agencies to implement dynamic windows without upfront capital costs and without the need for special Congressional appropriations.

TECHNOLOGY DESCRIPTION

View's dynamic windows technology is highly innovative and represents a significant advancement over the current state-of-the-art in energy-efficient windows. The product operates by the electrochromic effect, reversibly changing color when a charge is applied. While electrochromic glass is not new, View's innovative approach results in a product that consumes 2x less energy and costs 4x less than the electrochromic glass available during the initiation of the demonstration project. These benefits make it a viable energy-efficiency technology for military installations. Figure 1 shows the windows in the "Tint 1 - Clear" and "Tint 4 - Dark" states.

DEMONSTRATION RESULTS

The project demonstrated a reduction in HVAC energy consumption of 29% compared to the existing windows baseline, corresponding to 2.2x greater energy savings than if we had upgraded to state-of-the-art low-e windows. Lighting energy was reduced by 62%, corresponding to 2.4x enhanced savings over upgrading with low-e windows. Total building energy savings was 28%, a 2.4x enhancement over upgrading with low-e windows. Economic assessment of this project estimates a payback of upgrading to View dynamic windows over state-of-the-art low-e windows of less than 3 years and a lifetime savings-to-investment ratio of 4.3.

Overall, the project was completed on time and on budget. All performance objectives were met or exceeded, and the host site has been enthusiastic and pleased with the impact on comfort in their building.

IMPLEMENTATION ISSUES

During this project, no significant implementation issues were encountered. Two minor issues were: 1) a very small population of the building occupants (2 of them) found the glare at the 4% tint state was still too high for their personal comfort during direct, full sunlight. In response, the software drivers were modified to reduce the maximum tint-state to 1%. There were no further complaints following this upgrade, and will ship future windows with this as a default setting; 2) we also found that it was important to accurately set occupant expectations upon conversion to dynamic windows. The glass is designed to predictively tint and clear to maximize comfort. This is a gradual process that may occur infrequently throughout the day. However, some occupants

expected the glass to transition quickly and often in response to non-comfort or energy conditions. This resulted in some concern, although it did not impact performance.

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1.0 INTRODUCTION

1.1 BACKGROUND

1.1.1 Energy Problem

Inefficient windows in buildings represent one of the biggest energy problems in the military today. Facilities consume 30% of all U.S. Department of Defense (DoD) energy demand. This massive energy footprint costs taxpayers billions of dollars each year and impacts DoD mission assurance by straining fragile public electricity grids. As such, it is no surprise that the DoD's #1 High Priority Performance Goal for 2011 was to "Reduce average building energy intensity." [1] Under Executive Order 13514, the DOD must improve building efficiency by 30% for all new building construction and 20% for all existing building major renovations. Since the vast majority of DOD facilities' electricity comes from commercial utility companies and grid infrastructure, energy security is directly related to the peak-load for the facility.

In the United States, over 50% of building energy is used for cooling, heating and lighting, all of which are directly impacted by windows. According to Lux Research, the thermal envelope impacts about 56% of total commercial energy consumption [2]. Windows are considered to be the "Achilles Heel" of the building envelope. They allow unwanted solar heat to enter during the summer via radiation and conduction, increasing cooling energy requirements and peak loads. They also allow internal heat to escape during the winter increasing season heating. Beyond negative energy impacts, current windows allow glare to reduce occupant comfort, allow for the over-use of window blinds, and the over-use of artificial lighting energy.

1.1.2 Impact of this Problem on DOD

A recent study concluded that two-thirds of the current 345,000 DOD buildings will be beyond their usable life within the next 15 years [3,4]. Under Executive Order 13514, the DOD must improve building efficiency by 30% for all new building construction and 20% for all existing building major renovations. Since the vast majority of DOD facilities' electricity comes from commercial utility companies and grid infrastructure, energy security is directly related to the peak-load for the facility.

Energy consumption by DOD impacts global operations by demanding enormous financial resources, constraining freedom of action and constraining self-sufficiency. In deployed environments, energy consumption puts many lives at risk in associated logistics support operations. As such, improving windows efficiency with significantly higher efficiency than today's state-of-the-art will not only reduce energy costs in order to refresh DOD's aging building-stock and allow DOD to meet the mandates of Executive Order 13514 in the coming decade, but it will also save lives.

1.1.3 Technology Opportunity

This ESTCP project demonstrated the benefits for DoD building energy efficiency with dynamic windows, a new type of advanced "Smart Window" product. These windows can automatically tint and untint throughout the day to minimize solar heat-gain in the summer, maximize passive

heating in the winter and the use of natural daylighting throughout the year. If broadly adopted, View's dynamic windows technology could reduce global DoD energy consumption from buildings by 15% and greenhouse gas (GHG) emissions by 24%, representing an annual savings of ~$680M. At the same time, replacing existing single pane windows with dynamic windows can reduce total facilities peak load by up to 25%, reducing strain on local electrical grid infrastructure, further improving energy security. Overall, the dynamic window technology addresses two of DoD's three key installation energy goals, to: 1) reduce energy usage/intensity and 2) improve energy security.

1.1.4 Technology Description

View's dynamic windows technology is highly innovative and represents a significant advancement over the current state-of-the-art in energy-efficient windows. The product operates by the electrochromic effect, reversibly changing color when a charge is applied. While electrochromic glass is not new, View's innovative approach results in a product that consumes 2x less energy and costs 4x less than the electrochromic glass available during the initiation of the demonstration project. These benefits make it a viable energy-efficiency technology for military installations. Figure 1 shows the windows in the "Tint 1 - Clear" and "Tint 4 - Dark" states.

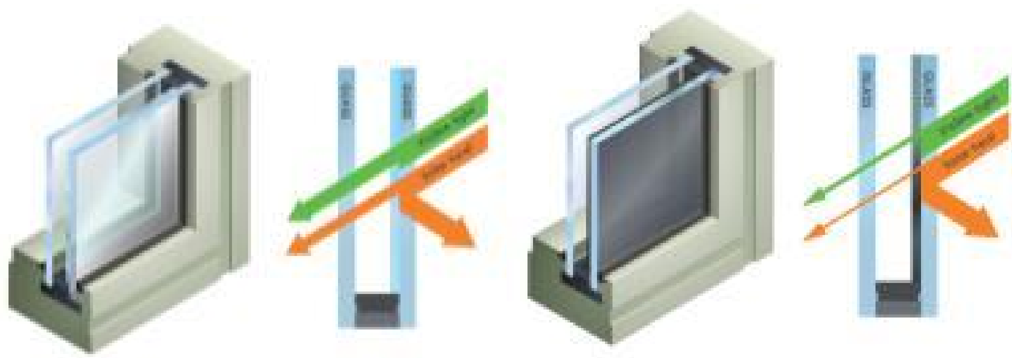

Figure 1. Cutaway view of an electrochromic window in the "Tint 1 - Clear" (left) and "Tint 4 - Dark" (right) states.

1.2 OBJECTIVES OF THE DEMONSTRATION

The goal of this project was to validate the performance and life-cycle cost benefits of dynamic windows in an operational environment, generating the data and insights needed to create awareness and acceptance of the technology. The project was intended to facilitate future technology transfer across all DoD building-stock, while providing a direct benefit to our host base in terms of reduced energy consumption, reduced life-cycle cost, and improved occupant comfort. These goals were accomplished by pursuing the following objectives:

1. Installed dynamic windows in a demonstration site on a DoD installation.
2. Monitored energy consumption, peak-load consumption and occupant comfort before and after installation.

3. Developed detailed energy models for the site and calibrated them against baseline and experimental energy results.
4. Used the calibrated models and historic weather data to predict the lifecycle energy savings (and resulting GHG and energy cost savings) at the site.
5. Used calibrated models to estimate reductions in peak-load energy use and improvement in occupant comfort to propose the ability to down-size the heating, ventilation, air-conditioning (HVAC) capacity and eliminate blinds/shades in future new construction and major renovation projects.
6. Quantified improvements in occupant comfort and satisfaction.
7. Quantified the total predicted life-cycle cost-, energy- and GHG-savings relative to state-of-the-art low-emissivity (low-e) windows at the site and across the entire DoD building stock.
8. Developed guidance documents and tools to assist with technology transfer across the DoD.

All goals and objectives were met for the project.

1.3 REGULATORY DRIVERS

Two important federal mandates are addressed by this technology:

1. Executive Order 13514: Federal Leadership in Environmental, Energy and Economic Performance [5]; and
2. Sustainability Rule for Procurement [6] under the Federal Acquisition Regulations (FAR).

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2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

2.1.1 Technology Description

View's dynamic window technology is highly innovative and represents a significant advancement over the current state-of-the-art in energy-efficient windows. The product operates by the electrochromic effect, reversibly changing color when a charge is applied. While electrochromic glass is not new, View's innovative approach results in a product that consumes 2x less energy and costs 4x less than the electrochromic glass available during the initiation of the demonstration project. These benefits make it a viable energy-efficiency technology for military installations. Figure 1 shows the windows in the "Tint 1 - Clear" and "Tint 4 - Dark" states.

The electrochromic device is formed via a stack of five (5) thin coatings applied to the inner surface of the outer pane of glass in an insulated glass unit (IGU). To darken the window, low voltage direct current (<5V) is applied, driving ions from one coating to the next, causing the stack to change tint and also to absorb light and heat. Reversing the voltage reverses the flow of ions. This also reverses the effect and transitions the stack back to a clear state.

By controlling the voltage, a dynamic glass glazing assembly can vary its solar heat gain coefficient (SHGC) from 0.46 to 0.09, and its visible light transmission from 58% transmission to just 3% total light transmission (Figure 2). In addition, intermediate tint states can be selected to optimize performance of the windows throughout the day. All key performance parameters can be found in Table 1.

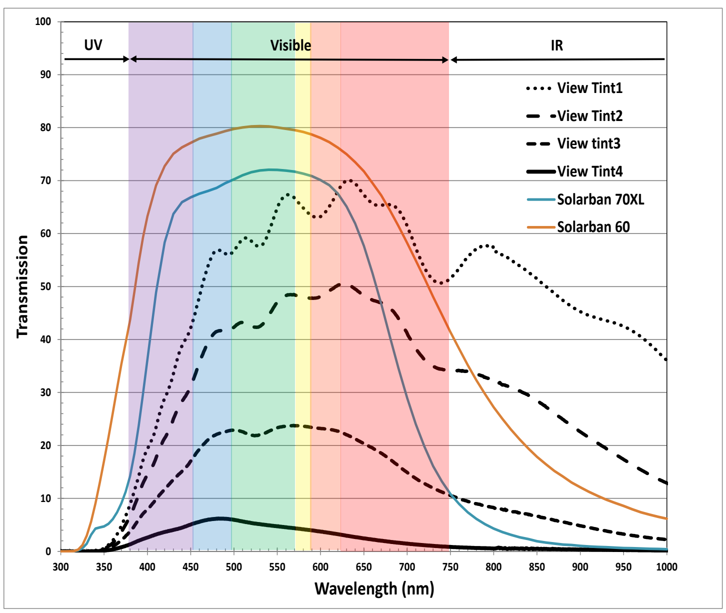

Figure 2. Electrochromic window configuration and optical characteristics plotted against low-e glass examples.

Table 1. View dynamic window performance characteristics (including intermediate states).

Tint Level	Transmittance (%) Visible	Transmittance (%) UV	Transmittance (%) Solar	Reflectance (%) Visible Out	Reflectance (%) Visible In	Reflectance (%) Solar Out	U-value	SHGC
Tint 1	58	3	37	18	20	18	0.29	0.46
Tint 2	40	2	21	12	19	12	0.29	0.26
Tint 3	20	1	8	8	17	11	0.29	0.16
Tint 4	3	0	1	7	17	11	0.29	0.09

UV = ultraviolet

Total energy consumption by these windows is negligible (1800 square feet [ft^2] of glass uses less power than a 60 watt [W] light bulb). All energy calculations in this proposal include this small energy consumption.

2.1.2 Technology Development To-Date

At the start of this project, View's dynamic windows were a fully-developed pre-commercial technology. The maturity of this technology was well-aligned with ESTCP. All laboratory and proof-of-concept work was complete [7]. Extensive durability testing and performance data from our windows had been collected under full operating conditions by the National Renewable Energy Laboratory (NREL), validating their capabilities to a 50+ year rated lifespan. Full-size prototype windows were already being produced at View's high-volume manufacturing plant in Mississippi [8]. This ESTCP project was the first demonstration of this technology at a DOD facility.

During the term of this ESTCP project, View has made tremendous progress on the commercial sale of this product, and now has more than 100 installations, with 50 more currently underway. This has not only provided additional validation of the results and reliability established under this ESTCP project, but is also providing significant economies-of-scale to drive-down costs. Both benefits can be leveraged by DOD for future installations.

2.1.3 Technology Development under Contact

All technology development was completed in advance of initiating this ESTCP project.

2.1.4 Applications of the Technology

This technology is applicable to virtually all of the DoD building stock, including both new construction and retrofits to the hundreds of thousands of buildings that currently feature aging, inefficient windows. This technology is particularly high-value in new construction, where the enabled capital avoidance can often completely offset the increased cost of the dynamic windows, generating all of the benefits demonstrated here at no net additional cost. Retrofit scenarios can also be compelling when the installation of dynamic glass is scheduled to coincide with an HVAC replacement. This technology has already generated strong enthusiasm among the DoD installation energy managers who were approached during this project, and who visited

our host-site to see the technology in action. Multiple new DoD projects are currently in the planning stage.

2.1.5 Impact on LEED and ASHRAE Requirements

Use of dynamic glass is explicitly recognized and accepted by the current American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standards. ASHRAE 90.1 – 2013 describes the specific treatment of dynamic glass in determining project compliance either by the prescriptive or performance paths. With technology/product acceptance ensured, dynamic glass is a preferred project component based upon its energy performance and code required savings objectives. When used in a new construction or renovation project, it can have a beneficial energy impact of 5-20% total building energy savings. That incremental savings can be crucial to making a project compliant with the current standard.

Beyond minimum code requirements, the use of dynamic glass can often offset other capital-intensive building elements required for high performance or Leadership in Energy and Environmental Design™ (LEED) certified design, as required for Federal new construction and deep renovations. As an example, the promotion of ample daylighting (75% of floor area) drives larger window area and often requires the use of expensive external shades, louvers or light shelves. Or, in the case of hospital settings, operable shades are often encapsulated within the insulated glass unit to minimize the exposure of infection prone materials to the patient. Dynamic glass eliminates these measures with a single solid state solution delivered at a lower net first cost.

2.1.6 Antiterrorism Standards

Dynamic glass technology is compliant with UFC-4-010-01. Specifically, the completed ESTCP project demonstrated compliance with UFC directives including "DoD Minimum Antiterrorism Standards for Buildings" (4-010-02) and to the updated requirements applying to "New Construction" and "Existing Buildings." Also, we are aware that recently four CCRs have been submitted with regard to the use of chromogenic (dynamic glass). These include:

- UFGS 08 51 13 Aluminum Windows (CCR submitted 2014-07-09 17:06 UTC);
- UFGS 08 60 45 Skylights and Translucent Panels (CCR submitted 2014-07-09 17:22 UTC);
- UFGS 08 81 00 Glazing (CCR submitted 2014-07-09 17:38 UTC); and
- UFC 3-101-01 Architecture (CCR submitted 2014-07-24 19:33 UTC).

Third-party certification of View dynamic glass windows was completed as part of this project, and can be found in Appendix I of the project's Final Report.

2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

2.2.1 Alternative Technologies

Windows technology today represents a compromise of the DoD's competing of energy efficiency and workplace performance objectives. Clear double pane IGUs provide thermal insulation and natural lighting, reducing interior heating and artificial lighting. However, these IGUs allow significant unwanted solar heat-gain to enter the building, increasing the size and consumption of HVAC systems due to a higher cooling load. Tinted and reflective IGUs provide thermal insulation and block solar heat-gain, reducing cooling and heating, but they also block natural light, increasing lighting requirements inside. Modern low-emissivity ("low-e") IGUs attempt to balance these extremes by blocking some solar heat-gain while allowing for natural light to pass. However, they are still a compromise striking a single performance value for both summer and winter conditions for the life of the product. This leads to significant annual lighting and heating energy consumption. Further, these static low-e IGUs do not control glare, therefore requiring the use of blinds and limiting the use of daylighting. Typical practice leads to blinds that are often left in the closed position all day, significantly exacerbating lighting energy consumption beyond what building managers intend or budget for. Dynamic glass is a technical response maximizing daylight, energy efficiency, and comfort in response to the outdoor conditions.

2.2.2 Advantages and Limitations of Dynamic Windows Compared to Low-E Windows

Advantages: There are significant benefits of dynamic glass compared to low-e windows:

1) Cuts solar heat by 4x in the summer,
2) Increases solar heat by 33% in the winter,
3) Reduces whole-building peak-load by up to 2x more,
4) Reduces glare by 23x,
5) Improves daylighting by 10x, and has
6) More than 4x higher life-cycle cost savings.

Limitations: The limitations of dynamic windows compared to low-e are minor and have been minimized through intelligent engineering:

1) *Higher Up-Front Cost:* The installed cost of dynamic windows is 50% higher than a comparable low-e system. However, this cost is easily offset by the reduction in HVAC capital expense, elimination of replacement blinds and their maintenance, and lifetime energy savings. For many installations, dynamic windows can be installed with a net cost at or below the cost of renovation with traditional low-e windows.

2) *Slightly More Complicated Installation:* Dynamic windows require low-voltage wiring and control systems, but do not require a licensed high-voltage electrician for installation. This wiring is akin to installing data network or alarm cables in the building.

3) *Single pane size limitation of 5ft. by 10ft:* While traditional glass can be produced in larger formats, the 5ft x 10ft max size addresses 90% of the existing glass market. It also represents nearly 100% of the existing DoD building stock.

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3.0 PERFORMANCE OBJECTIVES

The Performance Objectives (PO) for this project directly relate to energy security, cost-avoidance, GHG emissions and occupant comfort. They were generated based on the direct measure of the impact of dynamic windows on a previous small pilot installation. This demonstration project successfully achieved all PO. For further details on technical performance, please see Appendix J in the project's Final Report.

Table 2. Summary of performance objectives.

Performance Objective	Metric	Data Requirements	Success Criteria	Results
1. HVAC Energy Usage	Average energy intensity (kWh/ft^2)	Sub meter readings for HVAC + lighting loads for the original building and for the building with View dynamic glass Modeled savings for the building with low-e	>10% annual energy savings over original building baseline 2x increase in energy savings compared to modeled low-e glass performance	29% savings over existing building baseline 2.2x increase in energy savings compared to modeled low-e glass performance
2. Building Peak Load Requirement	Peak Power Intensity (kW_{peak}/ft^2)	Meter Readings during peak load for original building and the building with View Dynamic Glass Modeled results for the building with low-e	>25% reduction in peak load requirement vs. original building 2x reduction in peak load compared to modeled low-e glass performance	27% reduction in peak load requirement vs. original building 2.5x reduction in peak load compared to modeled low-e glass performance
3. Life-cycle GHG Emissions	Metric tons	Modeling data for original building, low-e and View Dynamic Glass, International Organization for Standardization (ISO)14044-compliant lifecycle modeling	2x reduction in lifecycle GHG emissions compared to modeled low-e glass performance	2.3x reduction in lifecycle GHG emissions compared to modeled low-e glass performance
4. Life-cycle System Economics	Dollars spent	Calculations using building lifecycle cost of projected energy cost-savings, and capital and maintenance savings	2.9x increase in life-cycle cost savings compared to modeled low-e glass performance	4.3x increase in life-cycle cost savings compared to modeled low-e glass performance
5. Occupant Comfort	%	Feedback from Likert-type comfort survey	Statistically significant gains in occupant comfort	Overall "comfort" increased by 15% to 96% (very high)
6. End-User Awareness & Acceptance	%	Feedback from Likert-type satisfaction survey	Statistically significant user satisfaction rates based on survey	Overall "satisfaction" increased by 31% with dynamic windows, to 98% (very high).

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4.0 SITE DESCRIPTION

This demonstration was undertaken at Marine Corps Air Station (MCAS) Miramar in southern California. The specific facility was Building 6311, the Installation and Logistics building, also known as “City Hall.” The climate at Miramar is a representative mild climate zone. As such, the savings with dynamic glass in many other climate zones of the United States will be comparable or higher. For example, the energy savings for this site is comparable to the same building located in climates ranging from Houston and Atlanta to San Francisco. There are 20-30% higher savings achieved in more extreme climates, such as Miami, Phoenix and Las Vegas.

4.1 FACILITY/SITE LOCATION AND OPERATIONS

The selected site constitutes the heart of construction and energy management departments at Miramar. The building houses the Installation Director, Public Works Department, and Station Planning teams.

4.2 FACILITY/SITE CONDITION

Building 6311 is a 32,000 square foot U-shaped office building (Figure 3). The project scope included replacing the windows on the east, west and south facades, for a total of ~1807 ft^2 of glass.

Figure 3. Floor plans for building (first floor is left, second floor is right).
The red stars indicate the facade depicted in the photo; heavy dashed lines indicate facades that were retrofitted with dynamic windows

4.2.1 Original Windows Details

In its original condition, the building was equipped with punched opening aluminum horizontal slider windows with single-pane and dual-pane clear glass that were designed to hold traditional dual pane IGUs.

Table 3. Baseline building window details.

Orientation of Window	U-value (W/m^2K)	SHGC	Visible Transmittance	Window to Wall Ratio
East	1.09	0.81	0.88	17.8%
West	0.48	0.47	0.38	32%
North	1.09	0.81	0.88	15.9%
South	1.09	0.81	0.88	18.4%

4.2.2 HVAC Details

Building 6311 was divided into 10 separate HVAC zones. All HVAC units are near their end-of-life, with a planned replacement within 12 months following the completion of this project.

4.2.3 Lighting Details

We installed light sensors and data-loggers to directly monitor lighting usage, rather than directly measuring lighting energy. The output from these sensors was used to calibrate our energy models, allowing us to make accurate estimates of the impact of dynamic windows on lighting energy consumption. In addition, the lights in this building were non-dimmable and did not have occupancy sensors. Because dimmable lights are now required by national model building code, we used our calibrated lighting model from our lighting data to accurately determine the energy impact expected for both dynamic windows and low-e windows in any future installations, which will necessarily include dimmable lights.

5.0 TEST DESIGN

5.1 CONCEPTUAL TEST DESIGN

5.1.1 Experimental Design

The scope of this project was to demonstrate the impact of dynamic windows via energy savings and HVAC peak-load reduction; to validate the performance and cost benefits predictions; and to provide empirical data useful to make realistic projections regarding the benefit of this technology across all DoD building stock. To accomplish this, we collected both quantitative and qualitative data addressing each of the key Project Objectives.

- Hypothesis: Dynamic windows will provide significant life-cycle energy and cost savings, energy security, and occupant comfort relative to low-e replacement glazing in a range of DoD applicable building types and climates.
- Test Design: Relevant zones of the existing building were sub-metered and logged to quantify the actual energy consumption of each building system in the treated zones. This data was correlated to environmental conditions and occupancy conditions. Sub-meter data was collected from the demonstration site throughout the test period – both before and after dynamic windows installation. A comprehensive and detailed energy model was developed using the Department of Energy's EnergyPlus software. The collected sub-meter data was used to calibrate the energy models so that predicted absolute and system relative consumption data matched the measurements.
- Independent variables: Glass type: a) original single pane glass (measured and modeled); b) insulated dual pane dynamic glass (measured and modeled); and c) dual pane low-e glass (modeled only).
- Dependent variables: 1) annual energy consumption; 2) HVAC peak load; and 3) occupant comfort. In addition to these variables, secondary impacts and cost-savings were calculated from: reduced HVAC capacity requirements; reduced operational costs associated with maintenance of the HVAC, blinds and curtains; reduced artificial lighting requirements; and reduced GHG emissions.
- Controlled variables: The major components of the building and its conditioning systems were not modified during the evaluation period. Example building systems include the exterior envelope, the major HVAC components (chiller, pumps, ductwork, controls), and the interior lighting. Occupant related control variables were also held fixed, including operating schedule, occupant density, and usage category (office/administrative)

5.2 BASELINE CHARACTERIZATION

5.2.1 Baseline Monitoring

The purpose of the baseline monitoring plan was to provide a baseline upon which the energy savings of dynamic windows could be compared; and to provide experimental data to validate and calibrate our baseline energy model (and thereby improve our dynamic and low-e models).

The reference conditions of the baseline characterization phase were those of the facility in its original condition. Electricity consumption of each HVAC unit was monitored via independent sub-meters in each HVAC zone. Additional data including the occupancy schedule, set point temperatures, setback temperatures, and weather conditions were also monitored. Lighting sensors were used to estimate lighting energy in different zones.

The baseline evaluation period was 5 months of continuous measurement, from December 2012 to May 2013. Local weather data was collected during this time period, and used in conjunction with metrological weather file data for annualized environmental load estimates, to annualize the expected baseline energy consumption for the full year. Occupant comfort surveys were assumed to represent historic daylight and glare preferences.

5.2.2 Baseline Occupant Surveys

Detailed surveys using standard 7-point Likert scales were developed by NREL to assess occupant comfort, satisfaction and productivity. These surveys were manually distributed to building occupants throughout the baseline period.

Overall, the detailed energy model correlated well with actual building energy consumption. Figure 4 shows our modeled energy consumption for a 12 month period, compared to the actual energy consumption for that same period. Also shown is the average measured monthly energy consumption for the whole building over our 5-month baseline monitoring period, compared to our modeled results. Both measurements matched our modeled results within 10%, indicating an acceptable correlation.

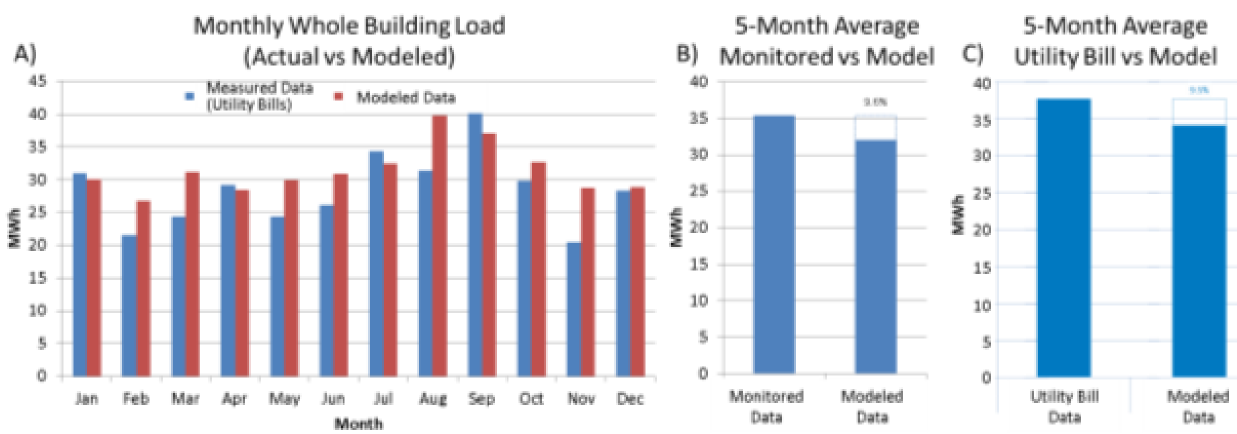

Figure 4. (A)Monthly average load for Building 6311 from our detailed energy model, compared to actual average monthly loads from utility bills over the same 12 month period in 2012.

Average building load over our baseline monitoring period (Dec-May, 2013), based on the project monitoring equipment versus modeled data (B). Modeled average load over the same period compared to actual utility bills (C).

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

5.3.1 Windows

All windows on the east, west and south facades were measured, and any special requirements for blast protection, beyond window and IGU parameters, were identified. Dynamic IGUs were fabricated by View, including 3/8" interior laminated glass, and integrated into Wausau 3250 Casement / Fixed Aluminum windows designed for DoD Minimum Anti-Terrorism Standards – UFC 4-010-01. Completed window units were delivered to the site for installation (Figure 5a). Existing windows and frames were removed (Figure 5b) and replaced with dynamic windows (Figure 5c), for a total of 1807 ft^2 of dynamic glass.

Figure 5. A) View dynamic glass IGUs received at Miramar. B) Construction crew removing old window frames. C) Final installed dynamic windows.

Installation was performed on a "rolling" basis, where occupants were moved from individual offices for a day, while the windows in that office were replaced, and then they were relocated into their offices. Over time, the entire building was retrofit, without major facility disruption.

Figure 6 shows the site before and after installation of dynamic windows. Note that, other than eliminating blinds and providing a more uniform look for the façade, there is no discernible change to the exterior façade. This will enable future energy efficiency upgrades to virtually all DoD buildings, including heritage buildings.

Figure 6. Western façade of Building 6311 before dynamic retrofit (left) and after (right).

5.3.2 Control Systems

Low-voltage power- and control-wiring was installed and routed to a central control panel, including independent in-line control units and central controls unit, located in the building's electrical room. Additional interior and exterior lighting sensors, integrated into the window frames provide individual control signals to each window, in addition to central networked control signals. Together this system is able to manage the performance of the dynamic windows to minimize energy usage and maximize occupant comfort based on interior and exterior lighting conditions.

The installed dynamic window system (hardware and controls) was fully automated and configured for the specific site location. It operates across a range of tint states (from clear to heavily-tinted) based on current environmental conditions such as temperature and glare. While the installed dynamic window system does not directly control the HVAC or lighting of the facility, those systems are designed to respond to building needs for heat and light to maintain their preset conditions (as is typical in all buildings).

The three systems, dynamic windows, HVAC, and lighting, operate independently (they do not control each other) but function in a complementary manner. For example, when the dynamic windows reduced the solar load in a room, the HVAC unit in that zone sees lower demand via its own room thermostat and trims its output according to its own internal control algorithm. Similarly, automatic lighting dimmers respond to occupancy and total illumination of each room, and automatically adjust to changes in tint by the dynamic windows throughout the day, based on the instantaneous daylighting available. This intrinsic automatic cooperation between systems dramatically reduced the installation cost of a fully integrated system in the building.

Additionally, the dynamic windows in each room can be controlled or overridden via a user wall switch or digital device (phone or tablet), or by the building automation system, whenever needed.

A graphical representation of the integrated dynamic windows and control system hardware is in Figure 7. The illustration shows the basic components of the façade and control components, and their physical relationship to each other.

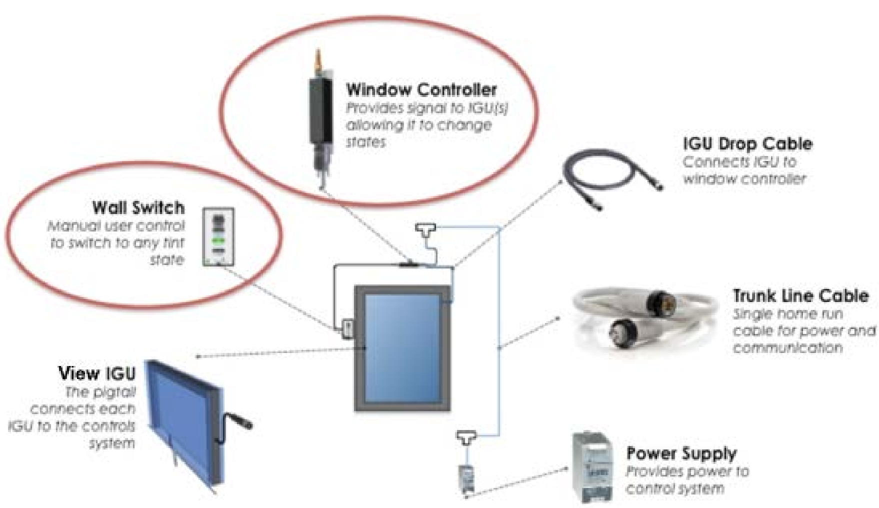

Figure 7. Dynamic window system. Controls are highlighted in red circles. The window controller determines automatic operation, while the wall switch allows direct user control.

5.4 OPERATIONAL TESTING AND SAMPLING PROTOCOLS

Commissioning and monitoring of the building post installation of the dynamic windows system was performed over a period of 6 months, from February to July, 2014.

5.5 SAMPLING RESULTS

5.5.1 Energy Consumption and Load Sampling Results

Figure 8 shows the average HVAC daily energy consumption of 4 different zones in the building, before and after retrofit with dynamic windows. These 4 representative zones provide insight into the impact of different building characteristics and uses on energy savings. The greatest savings found in zones with western exposure and in zones with higher window-to-wall ratios. Also worth noting, the HVAC energy in some zones of the building are dominated by the internal thermal loads of office equipment (example AC 7) so the HVAC energy savings are lower in those zones.

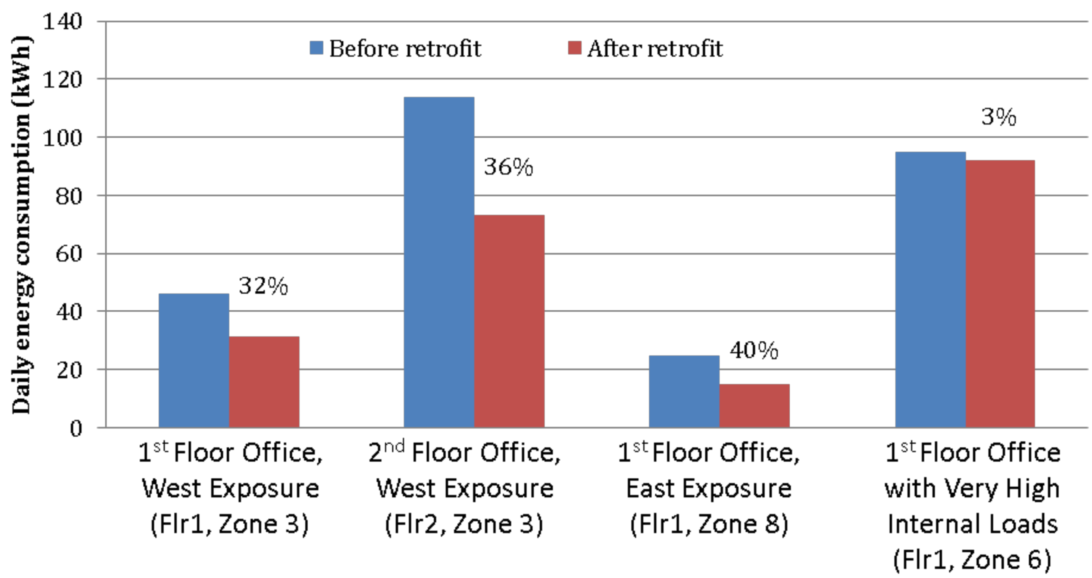

Figure 8. Plot of daily HVAC energy consumption in four representative zones, before and after dynamic windows retrofit.

Overall, energy savings in all eastern and western oriented offices were in the range of 30-40%. However, several zones with higher-than-normal internal loads (see 1st Floor, Zone 6) tended to shift the total building average results to lower values.

5.5.2 Lighting Sampling Results

From our lighting/occupancy sensors, we were able to track the lighting use in each switched zones throughout the building to estimate lighting energy usage. Figure 9 shows the average reduction in lighting energy use throughout the course of the day. Note that because existing lights in Building 6311 did not have dimmers, the savings seen in Figure 9 is a direct result of occupants actually turning off the lights when sufficient daylighting was available. Automated dimmers will do a significantly more effective job than this.

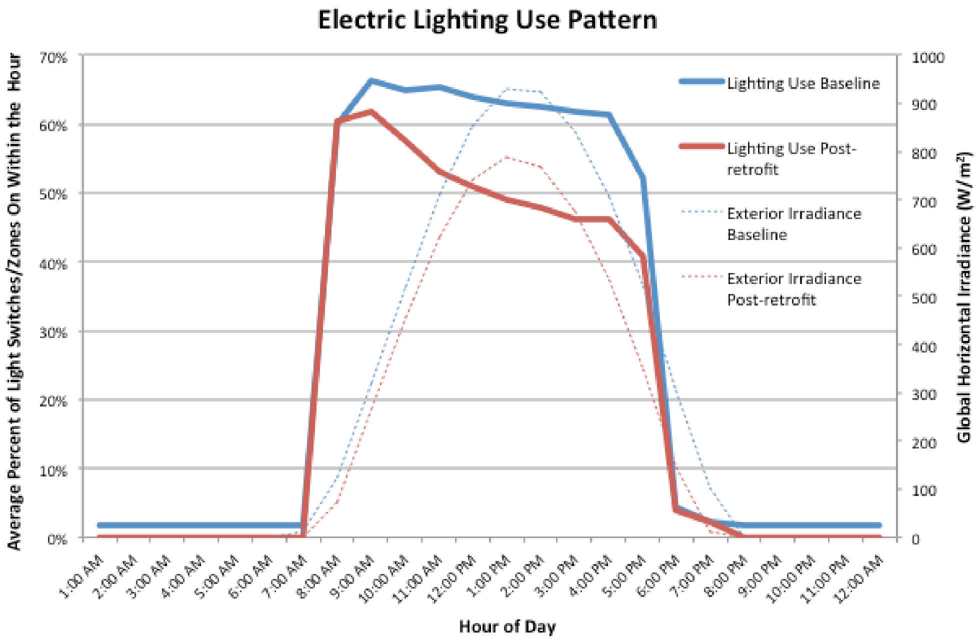

Figure 9: Average interior electrical lighting energy consumption throughout the day, with and without dynamic windows.

Also shown as dotted lines are the average exterior irradiance during each monitoring period.

5.5.3 Glare Reduction Sampling Results

Figure 10 shows the reduced glare resulting from View dynamic glass. This data was collected from a west-facing open office workstation.

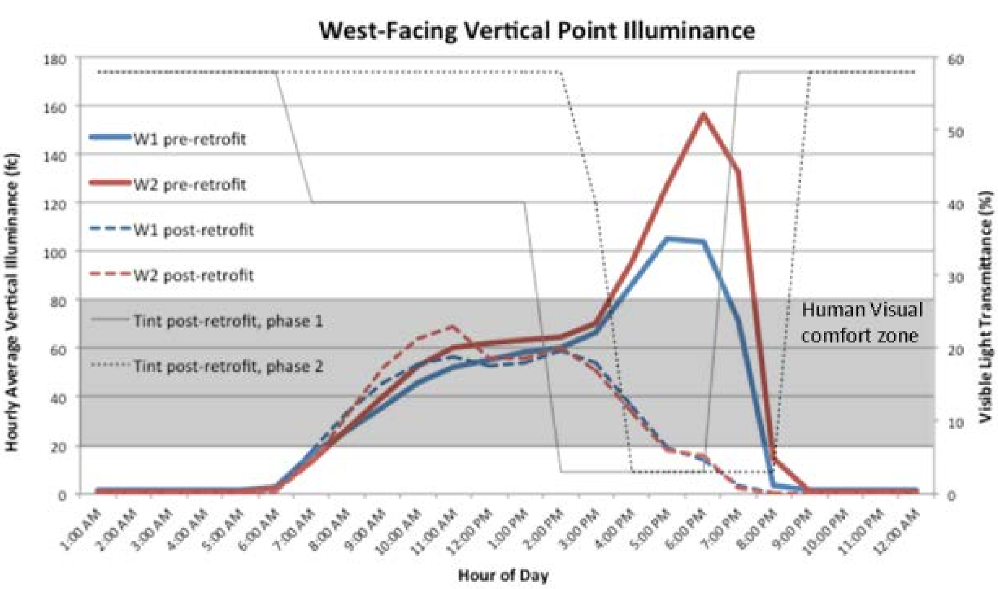

Figure 10. Illuminance measurements to determine glare.

Shown is the total illuminance at two locations, before and after installation of dynamic glass. The wide horizontal grey band is the range of illuminances generally accepted as "comfortable" by people.

6.0 PERFORMANCE ASSESSMENT

6.1 TOTAL BUILDING ENERGY IMPACT

Table 4 and Figure 11 show the total building energy load broken out by component, for the original building with single-pane windows, the building if low-e windows had been installed, and the building after installation of dynamic windows, including the relative energy savings in each case.

Table 4. Combined rules energy modeling results.

Total building energy consumption by component load for three building conditions: 1) the baseline (single-pane glass) building, 2) the building with low-e glass, and 3) the building with dynamic glass.

End Use	Baseline Glass (kWh/sqft/yr)	Upgrade to low-e (kWh/sqft/yr)	%-savings	Upgrade to Dynamic Glass (kWh/sqft/yr)	%-savings
Interior Equipment (electric)	4.21	4.21	0%	4.21	0%
Interior Lighting (electric)	3.77	2.82	25%	1.45	62%
Heating (electric)	0.035	0.041	-17%	0.044	-25%
Heating (gas)	0.10	0.14	-34%	0.18	-71%
Cooling (electric)	0.57	0.46	18%	0.36	37%
Fans (electric)	2.30	2.01	13%	1.66	28%
SWH (gas)	0.22	0.22	0%	0.22	0%
Total Building Energy	**11.20**	**9.89**	**12%**	**8.11**	**28%**

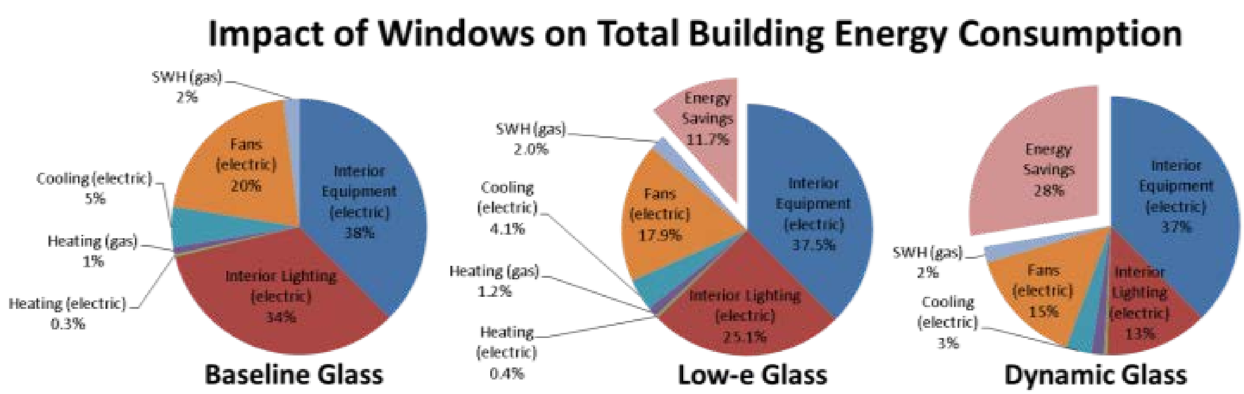

Figure 11. Impact of windows on total building energy consumption for three conditions: baseline (single-pane glass), low-e glass, and dynamic glass.

Overall, we see 2.5x greater savings on lighting energy by using View dynamic windows compared to low-e windows, from increased access to natural daylighting. We see a little over 2x greater energy savings on air-conditioning and fan energy with View dynamic windows than low-e, from reduced solar heat gain, plus reduced thermal load from electrical lighting. Overall, by upgrading to dynamic windows, we can reduce the total building energy by 28%, or 2.4x greater increase in energy savings than upgrading with Low-e (only 12%). Figure 11 shows the breakdown of key building loads in the original building, low-e and dynamic cases. Based on these results, the total lifetime energy savings for this building is 2,968,000 kilowatt hours (kWh).

6.2 HVAC ENERGY AND PEAK LOAD IMPACT

Figure 12 shows the average HVAC related energy consumption for building 6311 before and after dynamic windows. Across the whole building, the net average energy savings was 29%, compared to only 13% for low-e windows, corresponding to 2.2x higher HVAC energy savings.

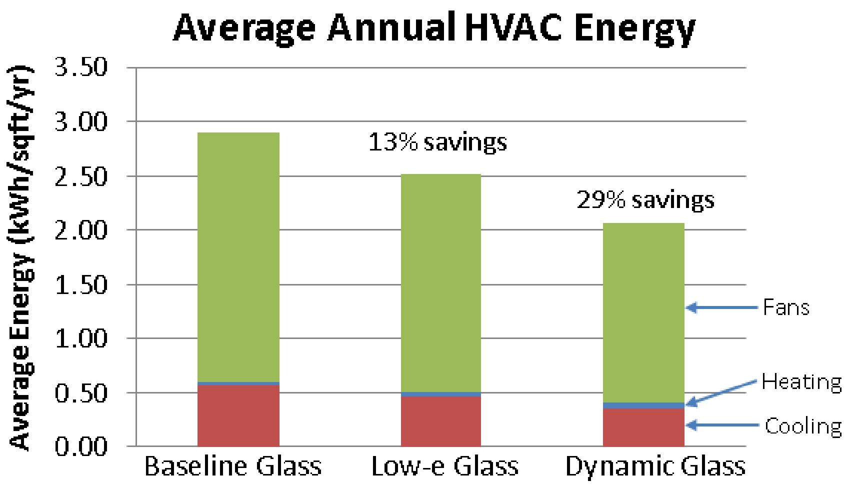

Figure 12. Average energy savings impact with low-e glass and with dynamic glass.

Use of dynamic glass has profound impacts on whole building HVAC system size and flow rate requirements. Building 6311 can reduce its system capacity by 27% and required flow rate by 28%. This is 2.4x and 2.7x greater reductions, respectively, than when upgrading with Low-e). As a result, the required equipment size of the pending and future HVAC replacements (average refresh every 15 years) can be reduced. This results in a significant capital expenditure savings over the lifetime of the dynamic windows. Table 5 shows the total cooling peak-load and fan peak-load for Building 6311 for the baseline, low-e and dynamic cases.

Table 5. Cooling capacity and flow-rate for Building 6311 under Baseline, low-e and dynamic window cases.

	Baseline	Upgrade with Low-e	%-Reduction	Upgrade with Dynamic	%-Reduction
Cooling Capacity	45 tons	40 tons	11%	33 tons	27%
Cooling Flow Rate	26420 cfm	23747 cfm	10%	19078 cfm	28%

Figure 13 shows the cooling loads coming from the façade (dominated by both the conductive and radiative solar loads) for the baseline and dynamic windows case.

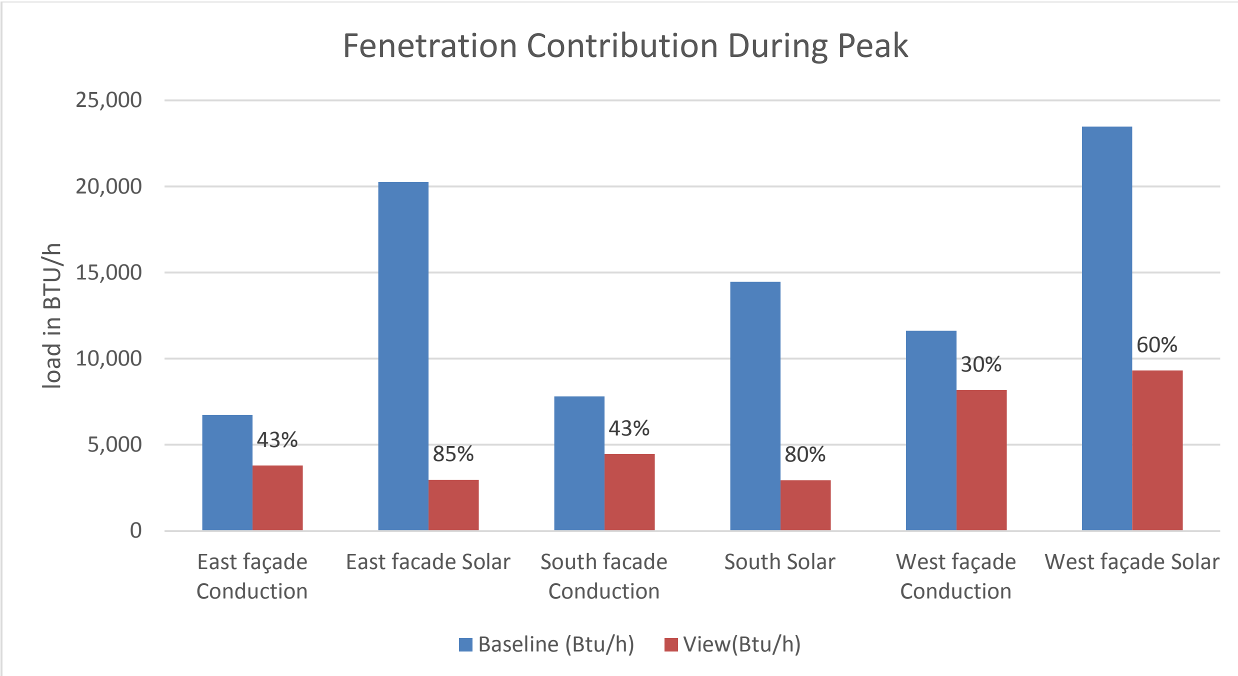

Figure 13. Reduction in HVAC load from per façade and load type (excluding internal loads) before and after dynamic windows.

6.3 LIGHTING

Figure 14 shows that daylighting control from dynamic windows with dimmable lights compared to low-e glass with dimmable lights has a significant impact on total building lighting energy.

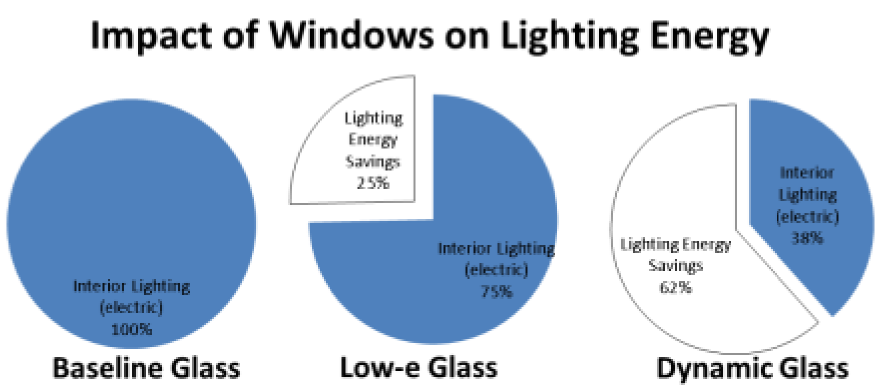

Figure 14. Impact on lighting energy from daylighting control of dynamic windows, compared to low-e windows.

6.4 LIFE-CYCLE GHG EMISSIONS

Life-cycle GHG emissions were calculated using standard ISO14044-compliant life-cycle modeling methodology based on the results of the energy analysis and projections described

above. Total GHG emissions were reduced by ~35% by retrofitting the building to dynamic glass. For this site, the total life-cycle GHG emissions will be reduced by ~5 million kilograms (kg) of Carbon Dioxide equivalent (CO2e).

Table 6. GHG emission reduction for Building 6311 from upgrading with low-e and dynamic windows.

GHG	Baseline (kg)	Low-e (kg)	Dynamic (kg)
CO_2	111455.3	94609	71642
CO	86.8	74	56
CH_4	579	491	372
NOx	95.4	81	61
N_2O	2.3	2	1
SO_2	1033.6	877	664

6.5 GLARE/OCCUPANT COMFORT

A comprehensive 7-point Likert Scale occupant comfort and satisfaction survey was completed before and after installation of dynamic windows. Occupant satisfaction increased significantly with dynamic windows in each of the three target areas of "comfort," "access to views" and "environmental control." Figure 15 shows the improvement in terms of percentage of positive responses. It is exceptional that the level of satisfaction for comfort and views is almost 100% with the dynamic windows condition.

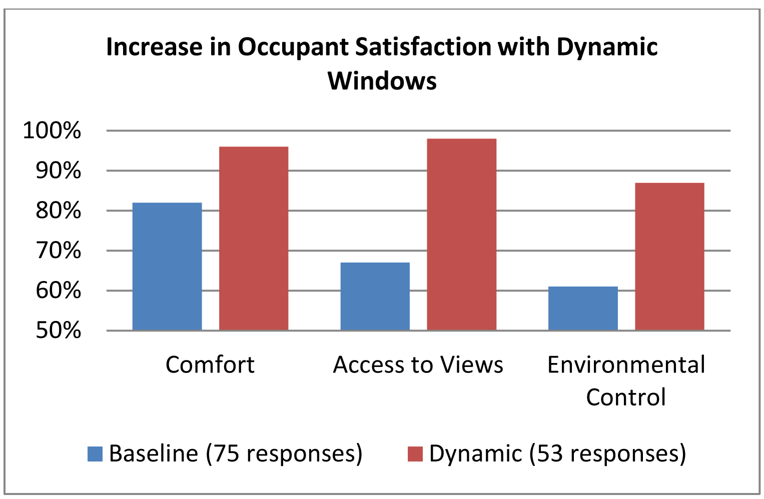

Figure 15. Increase of occupant satisfaction before and after the installation of dynamic windows.

7.0 COST ASSESSMENT

7.1 COST MODEL

In addition to developing models to predict the energy and greenhouse gas benefits of dynamic glass technology, the project team also developed an empirically derived economic model to assess the deployment costs and benefits for the installation site and for DOD building stock adoption. For this, several assumptions about expected project costs were made. These included:

Glass (IGU) Costs: The total cost from the glass vendor. This includes associated electrical components and commissioning for dynamic IGUs.

Shading Costs: Glare control blinds are assumed to be an installation requirement on low-e replacement windows, but not for dynamic windows. The cost for the installed blinds was assumed to be $\$15/ft^2$, with assumed average usable lifetime of 10 years and maintenance cost of $\$0.15/ft^2$/year.

HVAC Costs: The assumed average usable lifetime of a typical HVAC system is 15 years. (This estimate is deemed conservative. This service life can be significantly lower if they are poorly maintained, or are located in a corrosive environment.) HVAC maintenance costs were assumed to be 1% of system cost.

Energy: Energy results were derived directly from the validated Energy Plus whole building model, using current San Diego utility rates ($/kWh) with an average 2% annual increase.

Electrical Labor Costs: Electrical labor cost for wiring dynamic glass network system components throughout the façade and bringing power to the control box was calculated using the RS Means construction labor reference guide and actual quotes/bids from mechanical contractors and engineering firms for other dynamic glass installations.

7.2 COST DRIVERS

Using our measured data and energy models, we projected the future potential energy and cost savings were projected from the use of dynamic windows as compared to traditional low-e glazing at the site.

The model includes an analysis based on a simple return-on-investment (ROI)/payback and the total realized benefits over a 30-year lifecycle. Each analysis was broken into two categories of expenditures: capital expenditures (CAPEX), which captures all first time costs/savings including the HVAC system and peripheral components retrofit cost, and window shades/blinds costs. And operating expenditures (OPEX), which is a total of all reoccurring expenses/savings impacted by the efficiency measure on an annual basis. OPEX captures the costs associated with energy consumption, HVAC maintenance, and window shades/blinds maintenance.

7.3 COST ANALYSIS AND COMPARISON

The impact of View dynamic glass on annual energy and peak load reduction results in: 1) energy costs and demand charge savings, 2) capital equipment cost savings (e.g., HVAC downsizing and elimination of blinds/shades), and 3) maintenance cost savings (e.g. from HVAC and blinds). The economic impact of retrofitting with View dynamic glass was compared against retrofitting with low-e glass, both with dimmable lights. Table 7 shows the "first costs" of integrating dynamic windows as part a deep retrofit, showing a total net first cost increase of only 6% relative to low-e, while generating a net annual cost savings from dynamic windows of 34%. Table 8 shows the overall economic analysis for this site for the first year.

Table 7. First costs and annual operational costs for dynamic windows and low-e.
For ease of comparison, all costs have been normalized to square footage of installed glass. Costs per square footage of floor-space can be calculated by multiplying each value by 17.7 (32,000 ft^2 of floor space/1807 ft^2 of windows).

First Costs for Dynamic Windows versus Low-e Retrofits		
Component	**Low- E Glass System ($/sqft of window)**	**Dynamic Glass System ($/sqft of window)**
IGU	$20	$97
Window Frame	$30	$30
Installation Labor	$25	$28
Low Voltage Labor	$0	$2
HVAC Capex Cost*	$236	$190
Shading Capex	$15	$0
Total Net First-Cost	**$326**	**$347**
First Cost %-Increase	**NA**	**6.4% increase**

* HVAC cost normalized to the ft^2 of glass, by dividing the total capital equipment cost by 1807 ft^2 of glass

Annual Operational Expenses for Dynamic Windows versus Low-e		
Element	**Low-E Glass System ($/sqft of glass/year)**	**Dynamic Glass System ($/sqft of glass/year)**
Energy Consumption	$28.78	$21.58
HVAC Maintenance	$2.21	$1.66
Shading Maintenance	$0.17	$0.00
Total Annual Cost	**$31.16**	**$23.24**
Percentage Annual Savings	**NA**	**34% decrease**

As can be seen in Table 8, there are multiple potential savings from the use of dynamic glass. In terms of capital and operational savings, the use of dynamic glass saves $82,000 in HVAC equipment up-front, plus an additional $82,000 for future HVAC replacements during the lifetime of the windows (assumed to occur every 15 years) and $30,000 savings on HVAC maintenance during this same period. Dynamic glass also results in $27,000 in up-front savings for shading attachments, plus an additional $54,000 savings on future shading replacement during the lifetime of the windows (assumed to occur every 10 years) and $9,000 savings on shades maintenance during this same period. Finally, the use of dynamic glass saves

approximately $13,000 in electricity per year, or $390,000 in electricity savings over the lifetime of the windows. Overall, dynamic windows result in a $655,000 lifetime ROI.

Table 8. Year 1 CAPEX and OPEX comparison between upgrading with View Dynamic windows versus state of the art Low-e windows.

Façade Package	**Low-e**	**Dynamic**	
Glass	1,807 ft^2	1,807	
Internal Shading	Manual blinds	None	
Exterior Shading	None	None	
Dimmable lights	Yes	Yes	
First Time Costs (CAPEX)	**Low-e ($)**	**Dynamic($)**	**Difference (Savings)**
Glass installed cost	145K	293K	148K
Electrical labor	-	4K	4K
HVAC	426K	343K	(82K)
Internal shades	27K	-	(27K)
Total CAPEX	$597K	$640K	**$42K**
Annual Operating Costs (OPEX)	**($)**	**($)**	**Difference (Savings)**
Energy consumption	52K	39K	(13K)
HVAC maintenance	4K	3K	(1K)
Shading maintenance	0.3K	-	(0.3K)
Total OPEX	$57K	$42K	**($14.536K)**
***Assumptions**			
Low-e Glass cost	$20/ ft^2 glass cost; $68/ ft^2 installed cost	Energy consumption savings	25.6% from baseline energy consumption
View Dynamic Glass cost	$97/$ft^2$ glass cost; $155/$ft^2$ installed cost	HVAC Maintenance	1.0%/year of HVAC cost
Electrical labor (dynamic only)	$2.00/$ft^2$f	Internal shades	$15.00/$ft^2$
HVAC savings	7.0 ton reduction @ $1,600/$ft^2$	External shades	None
HVAC CFM reduction	4,669 CFM; $4.08/CFM	Shading maintenance	$0.15/$ft^2$/year
HVAC related components	19.7% reduction from baseline of $12/$ft^2$ of perimeter area		

Table 9 depicts the output of a standard NIST BLCCA analysis for this site. The Year 1 savings-to-investment ratio (SIR) is 0.82, with a payback of less than 3 years. The 30-year SIR is 4.3, with a total life-time cost savings of $655,000. This case study recognizes that View windows and state-of-the-art Low-e windows both have an expected lifetime of 30 years, as does Building 6311.

Table 9. NIST BLCCA cost analysis and 30-year savings to investment analysis.

Dynamic versus Low-E	**Years**				
	1	**5**	**10**	**20**	**30**
Initial Investment (Windows) ($k)	**151.9**	**151.9**	**151.9**	**151.9**	**151.9**
Other Capex Savings ($k)	109.6	109.6	136.7	219.2	219.2
Energy Savings ($k)	13.4	67.2	134.4	268.8	403.2

Maintenance Savings ($k)	1.1	5.5	11.0	21.9	32.9
Total Savings ($k)	**124.1**	**182.3**	**282.0**	**509.9**	**655.2**
Savings/Investment	0.82	1.20	1.86	3.36	4.31
Payback	**2.91 Years**				

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8.0 IMPLEMENTATION ISSUES AND LESSONS LEARNED

No significant implementation issues were encountered during this project.

8.1 INSUFFICIENT GLARE REDUCTION FOR SOME OCCUPANTS

A very small population of the building occupants (two total) found the glare at the 4% tint state was still too high for their personal comfort during direct, full sunlight. In response, the software drivers were modified to reduce the maximum tint-state to 1%. Since this adjustment, we have not received any further complaints. This feedback has prompted a revision and improvement to View's existing product. View has completed the development of a 1% tint product that will begin deploying in the first quarter of 2015. Initial customer feedback indicates that at 1% tint, glare deduction satisfaction exceeds 95% (up from the approximately 75% satisfaction rating with 4% tint).

8.2 PROCUREMENT AND INSTALLATION

View dynamic glass is positioned as a smart glass product designed for purchase and installation by DOD-qualified glazing subcontractors and low voltage subcontractors, as was the case with this project. For future installations, it should be noted that the local subcontractors control the product markup and installation pricing thereby varying based on the region. This potential issue can be mitigated through active training and education of installers.

8.3 STRUCTURAL LOAD

There were no structural load issues with the demonstration project. View dynamic glass weighs approximately the same as traditional low-e insulated glass units (approximately 4 pounds per ft^2) and replaced a mixture of single pane and dual pane existing glass. However, for future renovation and retrofit projects where single pane glass is being removed or added, a structural engineer should be included in the project and participate in early discussions.

8.4 WINDOW OPERABILITY

For this project, operable windows were replaced with inoperable (fixed) windows to optimize energy efficiency and HVAC load management. The conversion to inoperable windows caused an unforeseen reluctance to accept the design and environment change in their familiar office space. This was mitigated via training, user surveys and a closely monitored employee transition period. To mitigate this in the future, View dynamic glass is now available in operable windows.

8.5 OCCUPANT TRAINING

In concert with the technology deployment, occupant training should be scheduled to properly set expectations on glass tint transition time. The glass is designed to predictively tint and clear to maximize comfort. This is a gradual process that may occur infrequently throughout the day. However, some occupants expected the glass to transition quickly and often in response to non-comfort or energy conditions. If expectations are not aligned with the glass' purpose and performance, it may be rejected as a technology due to a misunderstanding.

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9.0 REFERENCES

[1] FY 2012 Budget of the United States Government, Fiscal Year 2012. It is often referred to as the “President's budget request”

[2] “Opening the Thermal Envelope: Emerging Innovation in Dynamic Windows and Advanced Insulation Webinar”, Lux Research, August 16, 2011.

[3] Office of the Deputy Under Secretary of Defense Installations and Environment, “Real Property Inventory Requirements Document”

[4] “Demonstrating the Relative Cost-Benefit of Reusing Historic & Non-Historic DOD Properties Using Scientifically-Derived Data”, Cherilyn Widell, Demonstration Plan, ESTCP Project Number SI 0931. Unpublished

[7] View grant progress report, Department of Energy Technology Laboratory, Funding Opportunity Number: DE-FOA-2010-0000115

[8] Ibid Reference MI plant PR

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APPENDIX A

POINTS OF CONTACT

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